Appendix E-3

Solar Photovoltaic Electrical Hazard Evaluation Checklist

**IMPORTANT USER NOTE: This document was created in 2014 and is based on Codes and Standards in force in 2014. To use this document properly, the user must refer to the code in force at the date of use.*

Purpose: This checklist for solar photovoltaic arrays identifies safe design requirements to protect against electrical hazards. There may be significant other hazards which are not addressed in this checklist. For example falls from rooftop systems is a common hazard. Integration of safe design is critical, as systems cannot be deenergized.

Requirements: Codes and standards for photovoltaic systems are rapidly evolving. Those promulgated after completion of the checklist and therefore not incorporated, are listed.

Applicability: This checklist is a tool to aid designers as well as those who maintain solar photovoltaic systems.

Solar Photovoltaic Electrical Hazard Evaluation Checklist

Number	Item	Y/N/NA
Electrical Hazards During Operations		
Troubleshooting Hazards		
1	Are the workers doing troubleshooting certified as qualified electrical workers for the equipment involved?	
2	Are workers wearing PPE, including appropriately-rated dielectric gloves, during troubleshooting?	
Equipment Failures		
3	Has the equipment that was subjected to SCC been inspected?	
4	Have records been updated for the equipment that was subjected to SCC?	
Exposures During Routine Maintenance		
5	Have shock and arc flash hazards been assessed prior to commencement of routine maintenance procedures?	

Solar Photovoltaic Electrical Hazard Evaluation Checklist

Number	Item	Y/N/NA
	Electrical Hazards During Commissioning Operations	
	Troubleshooting Hazards	
1	Are the workers doing troubleshooting certified as Qualified Electrical Workers for the equipment and potential hazards?	
2	Are workers wearing appropriate dielectric gloves during troubleshooting?	
	Equipment Failures	
3	Has the equipment that was subjected to short circuit current been inspected?	
4	Have records been updated for the equipment that was subjected to SCC?	
	Exposures During Routine Maintenance	
5	Have shock and arc flash hazards been assessed prior to routine maintenance procedures?	

Solar Photovoltaic Electrical Hazard Evaluation Checklist

Number	Item	Y/N/NA
	Electrical Hazards During Construction Operations	
	Use of Temporary Generators	
1	Are there direct-contact electrocution hazards?	
2	Are “quick connect” connectors being used?	
3	Have all backfeed sources been identified and LOTO, including:	
3a	Substation power transformers	
3b	Padmounted transformers	
3c	Station Power transformers	
3d	Instrument transformers	
4	Are grounding and bonding properly installed?	
5	Does the generator in use require a separately-derived ground?	
6	Are there any floated neutrals?	
7	Are equipment grounds effectively applied?	
8	Are there incident energy levels in excess of 10 cal/CM2?	
	Use of Temporary Wiring	
9	Are temporary extension cords in use?	
9a	Is so, are GFCI being used?	
9b	Are extension cords properly rated for the load, NRTL-listed, and in good condition (coating intact and repaired)?	
	Handling High Voltage Cables	
10	Are high voltage cables being used or worked on?	
10a	If so, are they effectively grounded ?	
10b	Are there situations were a XFMR backfeed could energize the high voltage cables?	
	Handling Photovoltaic Cells	
11	Are workers installing or connecting strings of PV cells?	
12	Does the DC circuit voltage exceed 800 volts?	
13	Are the workers wearing properly rated dielectric gloves?	

Additional Codes and Standards Related to Electrical Safe Design of Solar Photovoltaic (PV) Systems Promulgated Through 2015 Not Included in the PV Checklist

Note: These standards and requirements were promulgated AFTER the development of the PV checklist; they must be confirmed as included to assure a PV System's electrically safe design.

Code/Standard Number and Edition Year	Code/Standard Title and Summary
NFPA 70, 2014	*National Electrical Code (NEC)®* Article 690, "Solar Electric Systems" (A summary of changes are found at the end of this document.) Article 705, "Interconnected Electric Power Production Sources"
NFPA 1, 2015	*Fire Code* Requirements cover the full range of fire and life safety issues from fire protection systems and equipment and occupant safety in new and existing buildings to hazardous materials, flammable and combustible liquids, LP-Gas, and more.
NFPA 101, 2015	*Life Safety Code* The most widely used source for strategies to protect people based on building construction, protection, and occupancy features that minimize the effects of fire and related hazards.
NFPA 90B, 2015	*Standard for the Installation of Warm Air Heating and Air Conditioning Systems* Requirements that cover the construction, installation, operation, and maintenance of systems for warm air heating and air conditioning, including filters, ducts, and related equipment to protect life and property from fire, smoke, and gases resulting from fire or from conditions having manifestations similar to fire.

Code/Standard Number and Edition Year	Code/Standard Title and Summary
NFPA 5000, 2015	*Building Construction and Safety Code* Design criteria regulate and control the permitting; design; construction, alteration, and repair; quality of materials; equipment and systems; use and occupancy; demolition; location; and maintenance of all types of buildings and structures.
NFPA 850, 2015	*Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations* Recommended practice outlines fire safety recommendations for gas, oil, coal, and alternative fuel electric generating plants, including high voltage direct current converter stations and combustion turbine units used for electric generation.
NFPA 111, 2013	*Standard on Stored Electrical Energy Emergency and Stand-by Power Systems* Covers performance requirements for stored electrical energy systems providing an alternate source of electrical power in buildings and facilities in the event that the normal electrical power source fails. Systems include power sources, transfer equipment, controls, supervisory equipment, and accessory equipment needed to supply electrical power to the selected circuits.
NFPA 70A, 2005	*National Electric Code Requirements for One and Two Family Dwellings* Created for electrical installers, contractors, electricians, inspectors, and builders who specialize in residential wiring, this document is a compilation of electrical provisions for one- and two-family dwellings that have been excerpted from the National Electrical Code®.
NFPA, 2013	*Fire and Life Safety Inspection Manual*

Code/Standard Number and Edition Year	Code/Standard Title and Summary
The Fire Protection Research Foundation, 2013	*Fire Fighter Safety and Emergency Response for Solar Power Systems Final Report, revised October 2013* This report assembles and disseminates best practice information for fire fighters and fireground incident commanders to assist in their decision making process for handling fire incidents in buildings equipped with solar power systems or in the systems themselves.
The Fire Protection Research Foundation, 2014	*Commercial Roof-Mounted Photovoltaic System Installation Best Practices Review and All Hazard Assessment, Feb. 2014* Compilation of information on electrical, fire, structural, and weather-related hazards and damage potential created by the installation of photovoltaic systems on commercial roof structures.
The Fire Protection Research Foundation, 2012	*Fire Safety Challenges of Green Buildings, November 2012* Develops a baseline of information on the intersection of “green building” design and fire safety and to identify gaps and specific research needs associated with understanding and addressing fire risk and hazards with green building design including PV systems.
IEEE 1547, 2003	*Standard for Interconnecting Distributed Resources (e.g., photovoltaic systems) with Electric Power Systems* (8 parts) Establishes criteria and requirements for interconnection of distributed resources with electric power systems.
IEEE 929, 2000	*IEEE Recommended Practice for Utility Interface of Photovoltaic (PV) Systems* Guidance regarding equipment and functions necessary to ensure compatible operation of photovoltaic (PV) systems that are connected in parallel with the electric utility which includes factors relating to personnel safety, equipment protection, power quality, and utility system operation.

Code/Standard Number and Edition Year	Code/Standard Title and Summary
IEEE 937, 2007	*IEEE Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic Systems* Design considerations and procedures for storage, location, mounting, ventilation, assembly, and maintenance of lead-acid secondary batteries for photovoltaic (PV) power systems are provided.
IEEE 1013, 2007	*IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stand-Alone Photovoltaic Systems* A method for determining the energy-capacity requirements (sizing) of both vented and valve-regulated lead-acid batteries used in terrestrial stand-alone photovoltaic (PV) systems is described.
IEEE 1361, 2003	*IEEE Guide for Selecting, Charging, Testing and Evaluating Lead-Acid Batteries Used in Stand-Alone Photovoltaic (PV) Systems* Stand-alone photovoltaic (PV) system parameters and operating conditions are discussed in relation to battery characteristics and expected system performance.
IEEE 1526, 2003	*IEEE Recommended Practice for Testing the Performance of Stand Alone Photovoltaic Systems* Tests to determine the performance of stand-alone photovoltaic (PV) systems and for verifying PV system design are presented in this recommended practice.
IEEE 1561, 2007	*IEEE Guide for Optimizing the Performance and Life of Lead-Acid Batteries in Remote Hybrid Power Systems* Applicable to lead-acid batteries that are used as the energy storage component in remote hybrid power supplies.

Code/Standard Number and Edition Year	Code/Standard Title and Summary
IEEE 1562, 2007	*IEEE Guide for Array and Battery Sizing in Stand-Alone Photovoltaic Systems* A method for properly sizing the PV array and battery for stand-alone PV systems where PV is the only charging source is recommended (in conjunction with IEEE Std 1013TM).
IEEE 1661, 2007	*IEEE Guide for Test and Evaluation of Lead-Acid Batteries Used in Photovoltaic (PV) Hybrid Power Systems* Specifically prepared for a PV/engine generator hybrid power system, but may also be applicable to all hybrid power systems where there is at least one renewable power source, such as PV, and a dispatchable power source, such as an engine generator.
IEEE 2030, 2011	*IEEE Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), and End-Use Applications and Loads* Provides alternative approaches and best practices for achieving smart grid interoperability.
IEC 62446, 2009	*Grid connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests, and inspection* Defines the minimal information and documentation required to be handed over to a customer following the installation of a grid connected PV system. Also describes the minimum commissioning tests, inspection criteria and documentation expected to verify the safe installation and correct operation of the system.
IEC 62253, 2011	*Photovoltaic pumping systems – Design quantification and performance measurements* Defines the requirements for design, qualification and performance measurements of photovoltaic (PV) pumping systems in stand-alone operation. The outlined measurements are applicable for either indoor tests with PV generator simulator or outdoor tests using a real PV generator.

Code/Standard Number and Edition Year	Code/Standard Title and Summary
IEC 62548, 2011	*Photovoltaic (PV) arrays – Design Requirements* Sets out design requirements for photovoltaic (PV) arrays including d.c. array wiring, electrical protection devices, switching and earthing provisions. The scope includes all parts of the PV array up to but not including energy storage devices, power conversion equipment or loads.
IEC 62109-1, 2010	*Safety of power converters for use in photovoltaic power systems -- Part 1. General requirements* Applies to the power conversion equipment (PCE) for use in photovoltaic systems where a uniform technical level with respect to safety is necessary. Defines the minimum requirements for the design and manufacture of PCE for protection against electric shock, energy, fire, mechanical and other hazards. Provides general requirements applicable to all types of PV PCE.
IEC 62109-2, 2011	*Safety of power converters for use in photovoltaic power systems, Part 2. Particular requirements for inverters* Covers the particular safety requirements relevant to d.c. to a.c. inverter products as well as products that have or perform inverter functions in addition to other functions, where the inverter is intended for use in photovoltaic power systems.

***Institute for Electrical and Electronics Engineering (IEEE) PV Standards:** http://www.solarabcs.org/codes-standards/IEEE/index.html

****International Electrotechnical Commission (IEC),** IEC Technical Committee (TC) 82 has written nearly eighty standards that pertain to photovoltaic: http://solarabcs.org/codes-standards/IEC/index.html